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GB 2366490 A
GB 2346516 A
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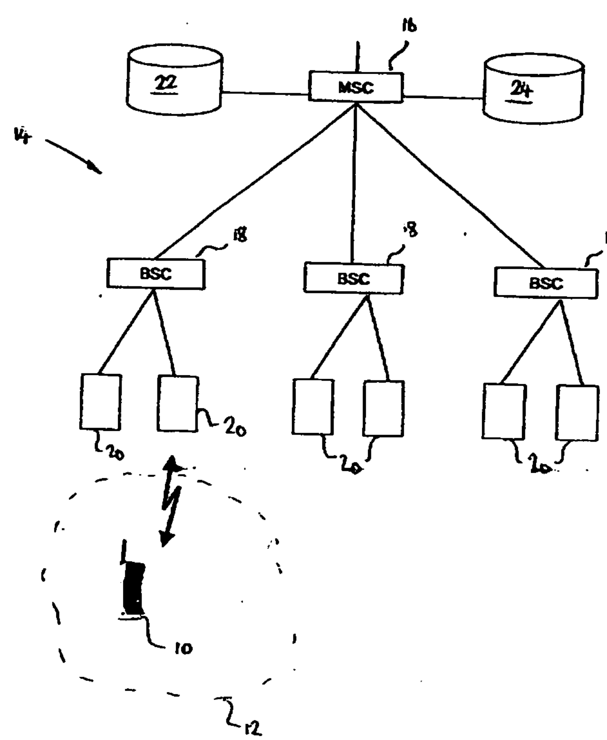
(54) Abstract Title
Location of a mobile terminal

(57) A mobile terminal 10 that determines its distance from at least 3 base stations 20 and hence its position. The positional information can be converted into geographical data base on the longitudinal and latitudinal information of the base stations. The distance calculations are and software controlled and performed by mobile terminal position determining module (PDM) receiving the timing advance (TA) signals from the base stations 20. The mobile terminal 10 can be used on a cellular telecommunications network that is GSM compliant where the base stations may be either the same network or different networks.

Fig. 1



GB 2 383 215 A

Fig. 1

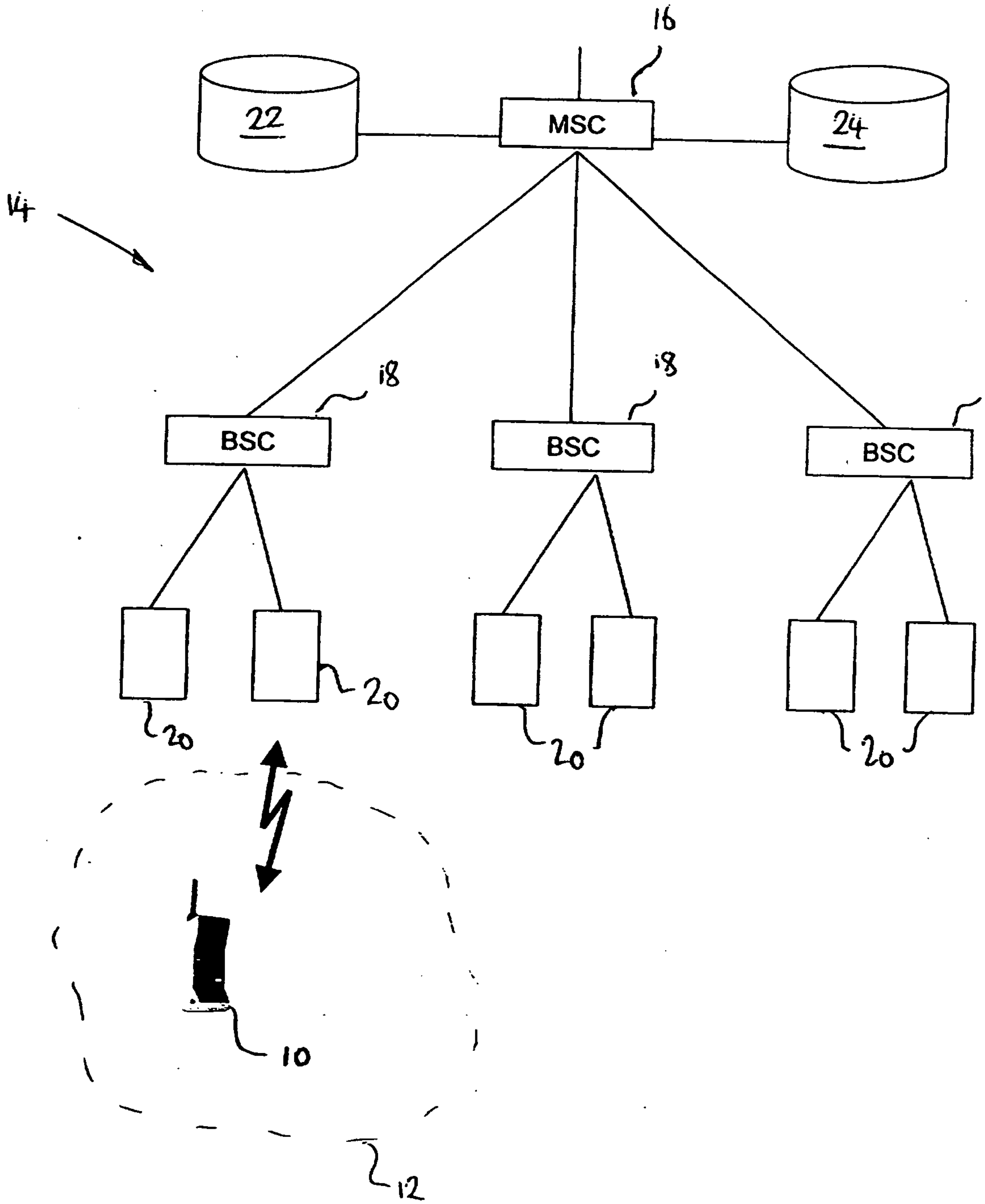


Fig. 2

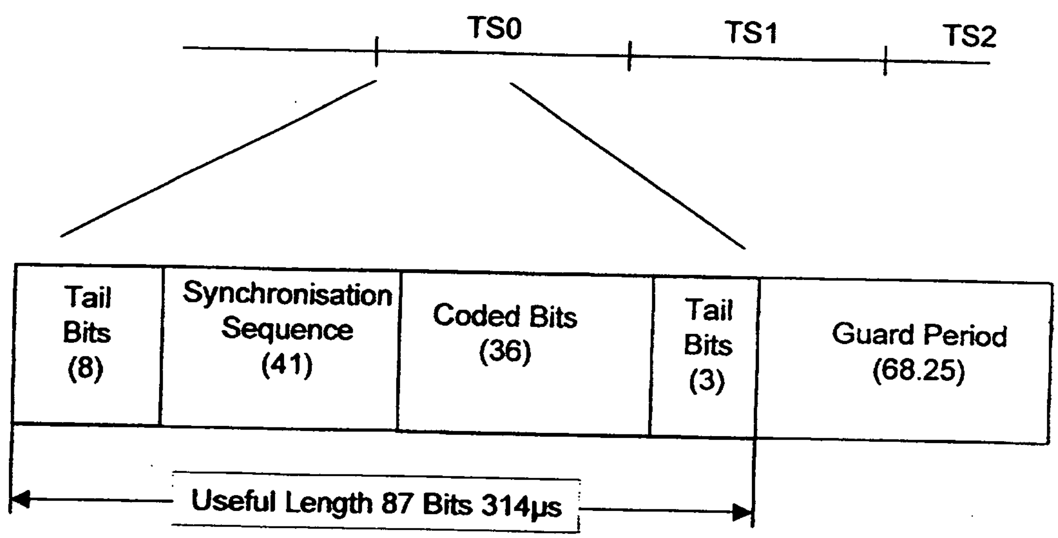
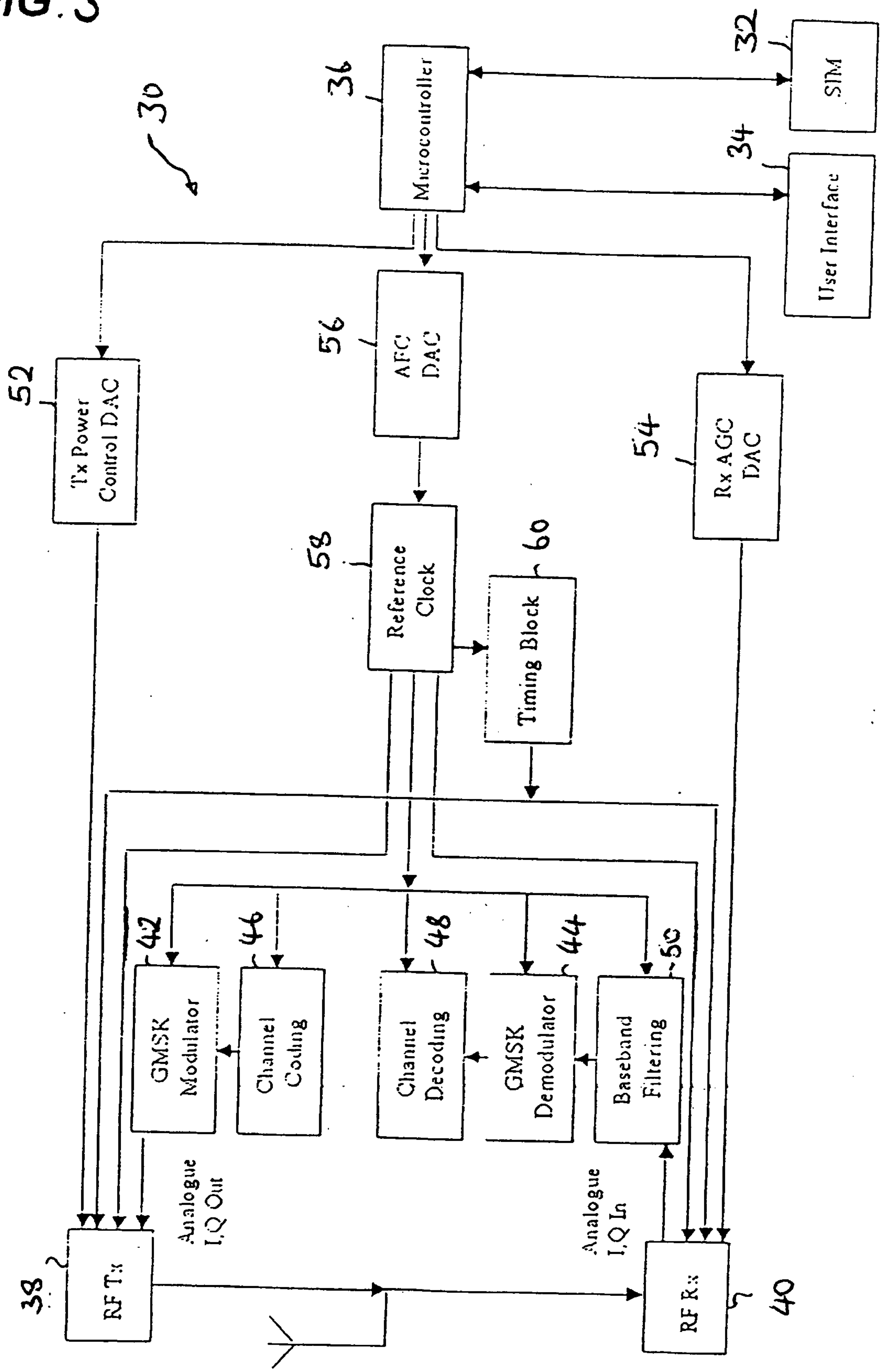

TS0
TS1
TS2
Tail Bits (8)
Synchronisation Sequence (41)
Coded Bits (36)
Tail Bits (3)
Guard Period (68.25)
Useful Length 87 Bits 314µs

FIG. 3



30
36
Microcontroller
32
SIM
34
User Interface
56
AFC DAC
52
Tx Power Control DAC
54
Rx AGC DAC
58
Reference Clock
60
Timing Block
42
GMSK Modulator
46
Channel Coding
48
Channel Decoding
44
GMSK Demodulator
50
Baseband Filtering
Analogue I,Q Out
Analogue I,Q In
38
RF Tx
40
RF Rx

Fig. 4

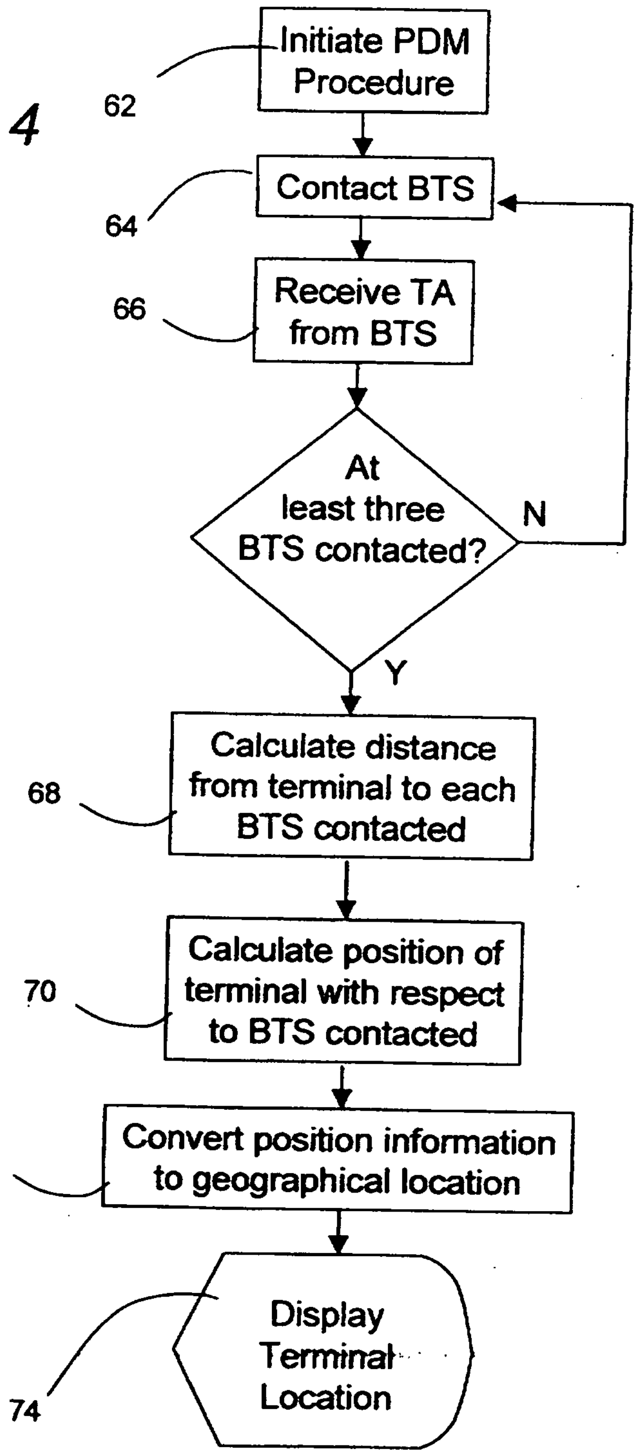
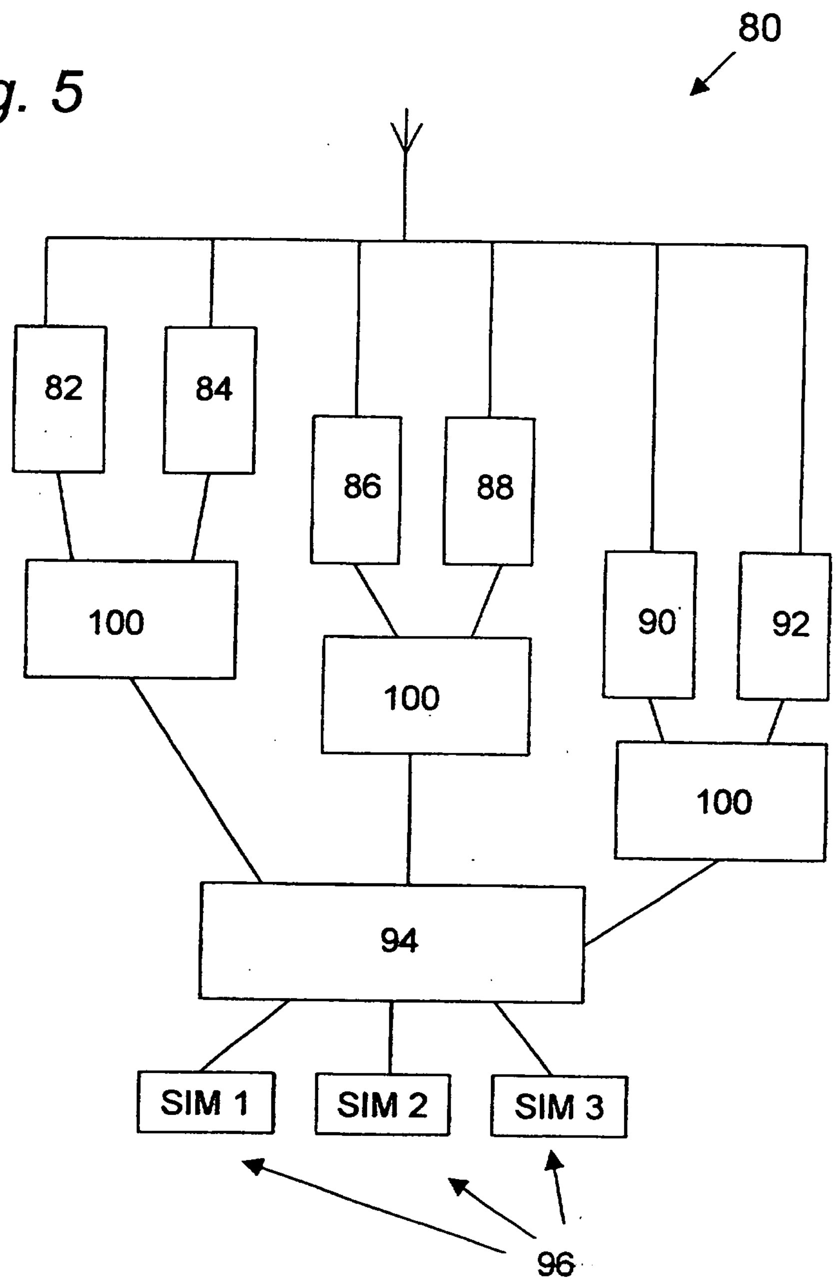
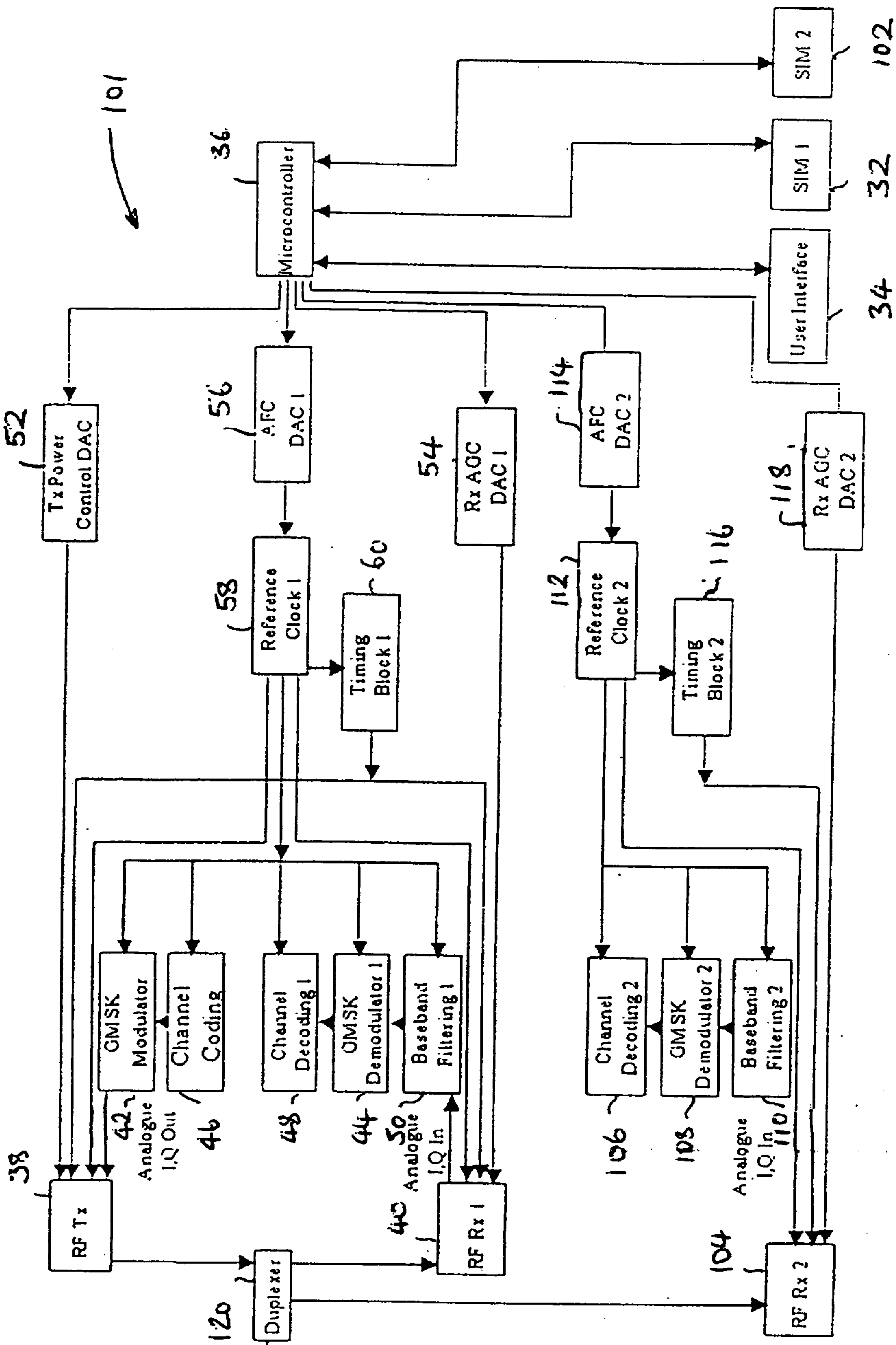

Initiate PDM Procedure
62
Contact BTS
64
Receive TA from BTS
66
At least three BTS contacted?
N
Y
Calculate distance from terminal to each BTS contacted
68
Calculate position of terminal with respect to BTS contacted
70
Convert position information to geographical location
72
Display Terminal Location
74

Fig. 5

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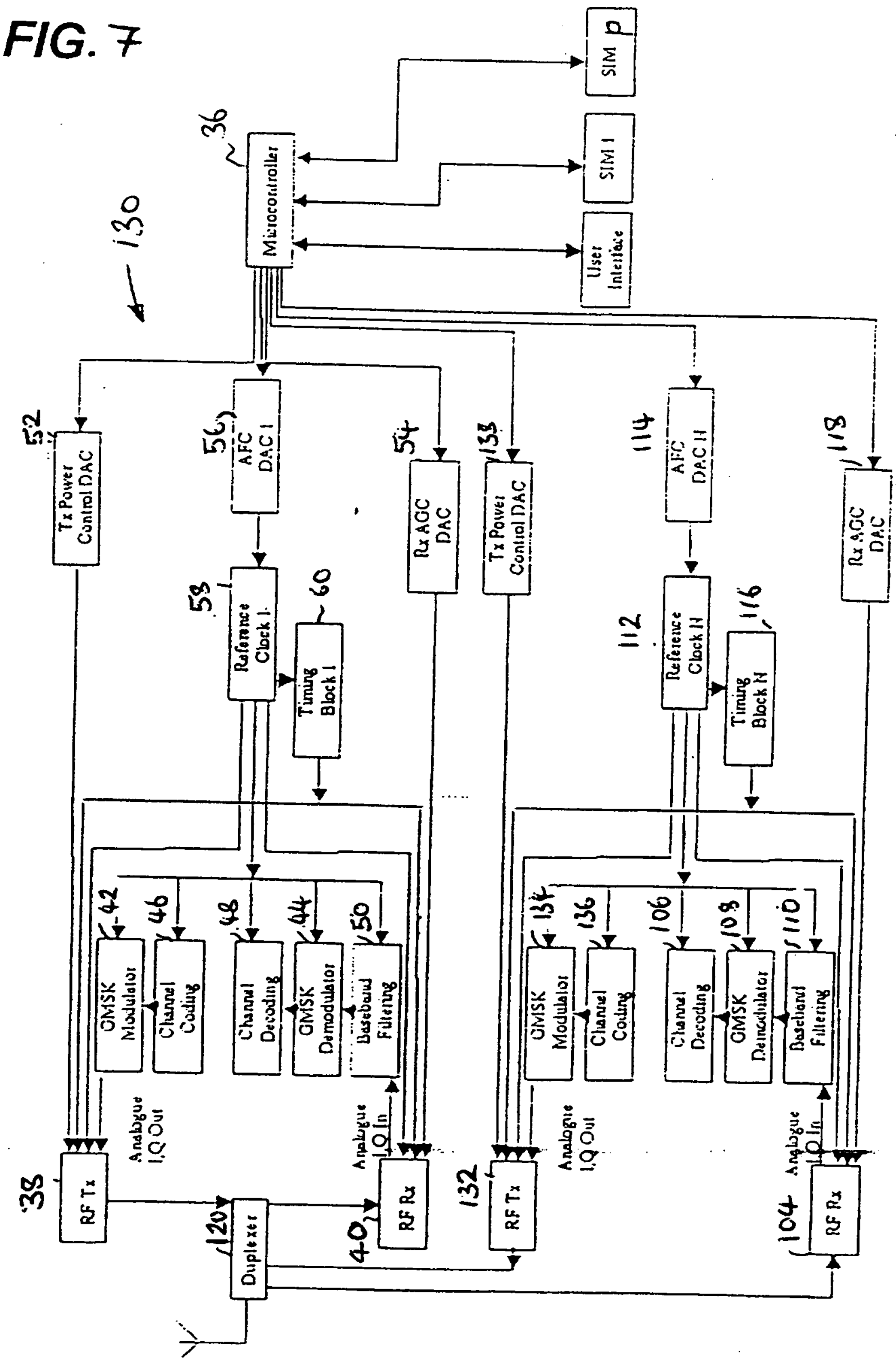
Microcontroller
36
SIM 2
102
SIM 1
32
User Interface
34
Tx Power Control DAC
52
AFC DAC 1
56
Rx AGC DAC 1
54
AFC DAC 2
114
Rx AGC DAC 2
118
Reference Clock 1
58
Timing Block 1
60
Reference Clock 2
112
Timing Block 2
116
GMSK Modulator
42
Channel Coding
46
Channel Decoding 1
48
GMSK Demodulator 1
44
Baseband Filtering 1
50
Channel Decoding 2
106
GMSK Demodulator 2
108
Baseband Filtering 2
110
Analogue I,Q Out
Analogue I,Q In
Analogue I,Q In
RF Tx
38
RF Rx 1
40
RF Rx 2
104
Duplexer
120

FIG. 6

FIG. 7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36
Microcontroller
SIM p
SIM 1
User Interface
52
Tx Power Control DAC
56
AFC DAC 1
54
Rx AGC DAC
133
Tx Power Control DAC
114
AFC DAC N
118
Rx AGC DAC
58
Reference Clock 1
60
Timing Block 1
112
Reference Clock N
116
Timing Block N
42
46
48
44
50
GMSK Modulator
Channel Coding
Channel Decoding
GMSK Demodulator
Baseband Filtering
134
136
106
108
110
GMSK Modulator
Channel Coding
Channel Decoding
GMSK Demodulator
Baseband Filtering
Analogue I,Q Out
Analogue I,Q In
Analogue I,Q Out
Analogue I,Q In
38
RF Tx
120
Duplexer
40
RF Rx
132
RF Tx
104
RF Rx

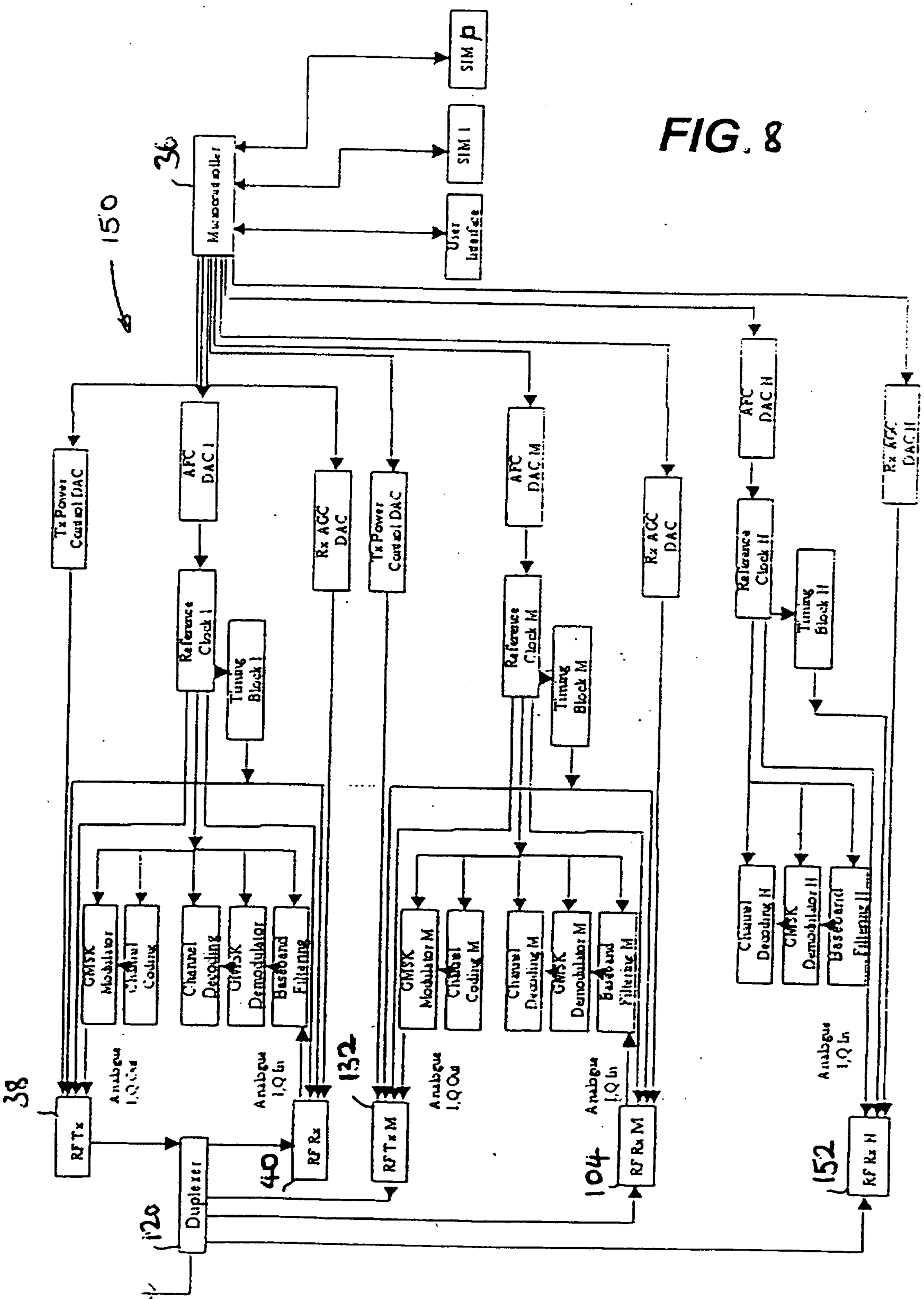
150
36
Microcontroller
SIM 1
SIM p
User Interface
Tx Power Control DAC
AFC DAC 1
Rx AGC DAC
Tx Power Control DAC
AFC DAC M
Rx AGC DAC
AFC DAC N
Rx AGC DAC N
Reference Clock 1
Timing Block 1
Reference Clock M
Timing Block M
Reference Clock N
Timing Block N
GMSK Modulator
Channel Coding
Channel Decoding
GMSK Demodulator
Baseband Filtering
GMSK Modulator M
Channel Coding M
Channel Decoding M
GMSK Demodulator M
Baseband Filtering M
Channel Decoding N
GMSK Demodulator N
Baseband Filtering N
Analogue I,Q Out
Analogue I,Q In
Analogue I,Q Out
Analogue I,Q In
Analogue I,Q In
38
RF Tx
40
RF Rx
132
RF Tx M
104
RF Rx M
152
RF Rx N
120
Duplexer

FIG. 8

MOBILE TERMINAL

FIELD OF THE INVENTION

This invention relates generally to mobile terminals (MTs), and in particular to mobile terminals for use in cellular telecommunications systems. Particular embodiments of the invention relate to mobile terminal position determination in such systems.

BACKGROUND TO THE INVENTION

As is well known, the Global Positioning System (GPS) can, at least in theory, enable anyone who is in possession of a suitable GPS receiver to determine their precise longitude and latitude (and in certain circumstances also their altitude) anywhere on the planet. GPS receivers used to be relatively large and expensive items of equipment, but in recent years they have become much smaller and less expensive. GPS receivers are capable of receiving signals from the 24 earth-orbiting satellites that make up the GPS network, and make use of a basic geometric principle known as triangulation to determine the location of the receiver. If the GPS receiver can only find three satellites, it can provide location information (i.e. longitude and latitude information) but no altitude information. For altitude information the receiver needs to find and communicate with a fourth satellite.

For a GPS receiver to determine its location, it looks up the location of at least three satellites from an electronic almanac maintained in the receiver, and then calculates the distance between itself and each of those satellites. To

calculate the distance between the receiver and each of the satellites, the receiver measures the amount of time it takes for signals from each of the satellites (which each include an atomic clock) to travel from the satellite to the receiver. Given that radio signals travel, at least approximately, at the speed of light it is possible to calculate how far they have travelled (and hence the distance from the receiver to the satellites) by calculating how long it took for them to arrive.

One might consider that an acceptable way to provide accurate position determination in a MT would be to combine a traditional MT with a GPS receiver. However, there are a number of problems and disadvantages associated with GPS receivers that preclude such a solution.

A first problem is associated with the fact that the speed of the radio signals from the satellites can vary with changing atmospheric conditions. Since the radio signal speed has a critical effect on the distance calculations, GPS receivers typically employ complex algorithms, and updating information from the satellites themselves, to compensate for atmospheric disturbances. If a GPS receiver were to be incorporated into a MT for connection to a cellular communications network, for example, then a disproportionate amount of processing time – and hence battery life – would be devoted to these calculations.

A second, more serious, problem is that as the GPS satellites are orbiting several thousand miles overhead, the satellite radio signals tend to be fairly weak by the time they reach the GPS receiver. As a result, the receiver

(or in this example the combined GPS receiver and MT) tends to need to be located outside in a fairly open area for it to function properly.

Another serious problem with the above proposal is that the resulting piece of equipment would have to be relatively bulky in order to fit all the electronic components inside the combined GPS / MT handset.

In an effort to avoid the inclusion of a GPS receiver in a traditional MT, it has previously been proposed to use radio signals transmitted between a base transceiver station (BTS) of the system and the MT to determine the geographic position or location of the MT in the cellular telecommunications system. Typically, this location information is destined for internal use by the network, and may have been requested by an external client or client application of the network. In cellular networks, such as for example the Global System for Mobile [tele]communications (GSM) or Universal Mobile Telecommunication System (UMTS) systems, it has been proposed to calculate the position of a given MT by locating the nearest base station or by more sophisticated methods such as measurement of round trip times (RTT) or OTDOA (observed time difference of arrival).

Proposals based on RTT or OTDOA measurements involve the determination of a transmission time T of a radio signal transmitted between a network node and a mobile station. Since the transmission velocity of the signal is known, the distance d between the node and the mobile terminal can be derived according to the relationship $d = T \cdot c$. Details of such location services (LCS) for GSM networks may be found in the GSM specifications

GSM 02.71 (digital cellular telecommunications system (Phase 2+) – Location Services (LCS); service description; Stage 1) and GSM 03.71 (Digital cellular telecommunications system (Phase 2+) – Location Services (LCS); Functional description; Stage 2) and for the third generation UMTS telecommunications networks in the Technical Specifications of the Third Generation Partnership Project 3G TS 23.171 (Technical Specification Group Services and System Aspects – Functional description of Location Services) and 3G TS 25.305 (Technical Specification Group Radio Access Network – Functional description of Location Services).

A disadvantage of methods employing RTT and OTDOA measurements is that the location accuracy can be substantially reduced if intermediate nodes, such as RF repeaters for example, are present in a particular cell of the network. In such a situation, signals from the BTS are received by the repeater, amplified and transmitted for reception by a mobile station; and as a result the signal ends up being transmitted over a distance which is greater than the direct path between the BTS and the repeater, or the BTS and the mobile station. In addition, these repeaters tend to introduce an internal time delay that further decreases the accuracy of the distance determination. As a result of this, RTT and OTDOA measurements are only really meaningful if they can be associated with the reference points – e.g. a base station or a repeater – and if it can be known whether the signal path was direct or via an intermediate node such as a repeater.

Another example of network implemented MT position determination

may be found in International PCT Patent Application No. WO 92/05672. The system described in this document makes use of so-called "timing advance" or TA signals that are normally transmitted from a base station to a MT when the MT initiates communications with that base station. The TA signals provide an indication to the MT of the extent to which the times at which signals are transmitted from the MT must be adjusted so that communications signals from the MT are received by the base station in the correct allocated timeslot. In the system disclosed, identity information from the MT and TA signals from at least three base stations are transmitted to a location unit that forms part of the network. The location unit then calculates the position of the MT using a so-called "circle method" which is broadly equivalent to the triangulation method employed by GPS systems.

A particular problem associated with the system described in this PCT application, is that whilst it works well in situations where the three chosen base stations are spaced a significant distance from one another, it can be quite inaccurate in situations where the base stations are relatively close to one another (as might happen in a city environment). European Patent Application No. 0930513 is directed to this particular problem and discloses a solution which involves instructing the mobile terminal, in dependence on which cell it is currently positioned in, to communicate with particular sets of base stations. The sets are each chosen so that, for a given cell of the network, the three base stations used will be sufficiently spaced to permit an accurate determination of MT position to be made.

Whilst these systems generally appear to work satisfactorily in most situations, there are circumstances where problems can arise. For example, in conventional TA based systems it may not always be possible to communicate with three base stations of a given network. This can be a particular problem in city environments where the high numbers of mobile users often means that base stations cannot be communicated with for significant periods of time.

Another significant disadvantage of these systems is that they can be very inaccurate when the MT is moving. In such circumstances, the MT must call three base stations in succession and it could well have travelled a significant distance (in a car for example) between calling the first base station and the third base station. In such a situation, it is likely that the location unit would be unable to generate three circles which overlapped at a specific point, and would instead only be able to determine that the MT is in an area somewhere in between the three circles.

A further significant disadvantage of network initiated mobile terminal position location is that as the position of the mobile terminal is determined by the network, so the location of the terminal becomes known to owners or operators of the network. As a consequence of this, network initiated position location has privacy implications which makes it less attractive to those mobile terminal users who do not wish their geographical position to be known to the network, or others.

It is an object of the present invention to mitigate these, and other, problems associated with the prior art.

STATEMENT OF INVENTION

In accordance with a preferred embodiment of the invention, there is provided a mobile terminal comprising means for determining the distance of the terminal from each of at least three base stations of one or more terrestrial communication networks; and means for calculating from said determined distances the position of said terminal with respect to said at least three base stations

Other preferred embodiments of the invention are defined in the independent claims, and associated preferred features of these embodiments are set out in the dependent claims, and elsewhere in this description

BRIEF DESCRIPTION OF THE DRAWINGS

Presently preferred embodiments of the invention will now be described, by way of example only, with reference to the following drawings in which:

Fig. 1 is a schematic representation of a GSM network;

Fig. 2 is a schematic representation of a GSM access burst;

Fig. 3 is a schematic representation of a conventional MT;

Fig. 4 is a flowchart illustrating steps of a method in accordance with a preferred embodiment of the invention;

Fig. 5 is a schematic representation of a MT in accordance with an embodiment of the invention; and

Figs. 6 to 8 are schematic representations of other MTs in accordance with embodiments of the invention.

Introduction to Preferred Embodiments

Before embarking upon a detailed description of the preferred embodiments, it is appropriate at this juncture to provide a brief introduction to the technology upon which this invention relies.

GSM Architecture & Protocols

Figure 1 provides a schematic illustration of a mobile terminal 10 in a cell 12 of a cellular telecommunications network 14, such as a GSM network for example. The present invention will be described with particular reference to a GSM network, but it will be appreciated by persons skilled in the art that the teachings of the invention are equally applicable to non-GSM compliant communications networks, such as a UMTS network.

As is well known in the art (see for example the aforementioned PCT patent application – WO 92/05672), a GSM communications network 14, for example, typically comprises a Mobile Switching Centre (MSC) 16 which is connected via communication links to a number of Base Station Controllers (BSCs) 18. The BSCs 18 are dispersed geographically across areas served by the Mobile Switching Centre 16. Each BSC 18 controls one or more Base Transceiver Stations (BTSs) 20 located remote from, and connected by further communication links to, the BSC 18. Each BTS 20 transmits radio signals to, and receives signals from, mobile terminals 10 which are in an area served by that BTS -- that area being referred to as the aforementioned "cell" 12. A GSM network is provided with a large number of such cells, which are ideally contiguous to provide continuous coverage over the whole network territory.

The mobile switching centre is provided with a Home Location Register (HLR) 22 which is a database storing subscriber data. The mobile Switching Centre 16 is also provided with a Visitor Location Register (VLR) 24 which is a database temporarily storing subscriber data for mobile terminals which are active in the area served by the Mobile Switching Centre 16.

Two interfaces are provided, namely a radio interface and an interface between the MSC and BSC. The radio interface adopts the standard OSI (Open Systems Interconnection) layered model, and in a GSM compliant communications system the physical layer of this model comprises a time division multiple access (TDMA) structure having eight timeslots per radio carrier. The TDMA structure is used by logical channels, in higher layers of the OSI model, and these channels are divided into traffic channels and control channels.

When switched on, a mobile terminal monitors broadcast channels BCCH of those base stations within range, and measures the strengths of the signals received from those base stations. This information is stored in a continuously updated table, and governs which of the various available base stations the mobile terminal will attempt to communicate with at any given point in time.

In the GSM system each TDMA frame is approximately 4.62 ms in length, and comprises eight timeslots each of approximately 577 μs in length. It takes approximately 3.69 μs to modulate a "1" or a "0" on a carrier signal,

and thus each timeslot (with an appropriate guard period) is capable of carrying 147 bits of useful information.

Each mobile terminal in communication with a given base station is allocated to a particular channel (i.e. timeslot) of a frame, and a function known as "adaptive frame alignment (AFA)" is employed to ensure that frames of different frequency channels are correctly aligned with one another. Generally speaking, AFA is employed to allow a mobile terminal to adjust its transmission timing to account for delays that will occur as a transmission signal propagates between the mobile terminal and a base station with which it is communicating. Without AFA, each mobile terminal would have to be synchronised exactly with each base station and this would be impractical, if not impossible, to achieve in practise.

AFA functions, generally speaking, as follows. When a mobile terminal first attempts to communicate with a particular base station, the terminal transmits what is known in GSM as an "access burst" on a random access channel (RACH). The access burst is 87 bits in length and is characterised, as shown in Fig. 2, by a long guard period of 68.25 bits which allows the access burst to arrive up to 63 bits late without slipping into the next timeslot.

When an access burst is received by a base station, the base station calculates the propagation delay from the position of the access burst in a given timeslot of the RACH. The delay is rounded up to the nearest whole bit period and then transmitted back to the mobile terminal as the aforementioned

TA signal. The mobile terminal receives the TA signal and advances its transmission timing by the number of bit periods specified in the TA signal to correctly synchronise its transmissions with the timeslot that has been allocated to it.

Since radio waves travel at the speed of light, at least roughly, it follows from the above that one bit period of 3.69 μs equates to a distance of approximately 1107m for the round-trip (mobile terminal to base station to mobile terminal), and hence to a distance of 553.5 m between the base station and mobile terminal. Thus, from the TA signal received by a mobile terminal from a given base station with which the terminal is attempting to communicate, it is possible to calculate the distance from the mobile terminal to that base station.

MOBILE TERMINAL ARCHITECTURE

Fig. 3 is a schematic representation of a known mobile terminal. In the particular example shown the mobile terminal is a telephone handset, but it will be appreciated that the mobile terminal need not be a telephone handset and could instead comprise a Portable Digital Assistant (PDA) or any other item of electronic equipment capable of wireless communications with a telecommunications network.

As shown, the handset 30 includes a subscriber identity module (SIM) 32. The SIM is coded with information to permit the user to access a telecommunications network operated by a particular network operator. Communications with the SIM 32, and input via a user interface 34, are

controlled by a microcontroller 36. The microcontroller also controls the transmission and reception of radio signals via a transmitter circuit 38 and a receiver circuit 40. Other elements of the handset include a GMSK (Gaussian Minimum Shift Keying) modulator 42 and demodulator 44, a channel coder 46 and decoder 48 and a baseband filter 50.

The microcontroller 36 is connected to a transmitter power control digital to analog converter (DAC) 52, a receiver automatic gain controller (AGC) DAC 54 and an automatic frequency correction (AFC) DAC 56. Timing is controlled by a reference clock 58 and a timing block 60.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

METHOD OF OPERATION

As mentioned above, a particular problem associated with prior art systems is that position determination can be quite inaccurate in situations where the base stations are relatively close to one another (as might happen in a city environment), or when the mobile terminal is moving. Another problem with conventional TA based position determination systems it may not always be possible to communicate with three base stations of a given network. A further problem with prior art systems is that network initiated position location has privacy implications which makes it less attractive to those mobile terminal users who do not wish their geographical position to be known to the network, or others.

To combat these problems, the mobile terminals of the preferred embodiments (to be described) are provided with a position determination

module (PDM) which is operable, in accordance with the method described below and shown in Fig. 4, to contact at least three base stations to receive TA signals therefrom. In the preferred arrangement the PDM comprises software, and could form part of a so-called SIM Toolkit (or SIM Application toolkit as it is sometimes known) or part of the software provided in the mobile terminal. As an alternative to software, the PDM could of course comprise hardware such as an application specific integrated circuit (ASIC), for example.

The PDM procedure can be initiated (step 62) automatically or in response to an instruction input by a user of the terminal. The instruction may comprise, for example, a depression of a key (which may be a key dedicated to the PDM procedure) or the selection of a PDM item from a menu of items.

Once the procedure has been initiated, the first step (step 64) is to contact a base station. Generally, the contact procedure is any procedure which causes the base station contacted to transmit TA information. However, if the mobile terminal is to operate with the GSM rules, then the contact procedure must be a registration, a call, an SMS text message or any other procedure which requires the assignment of a dedicated channel.

As an alternative, it may be possible to modify the GSM rules to include a new PDM procedure which allows base stations to transmit TA information without having to subsequently set up a dedicated channel to that base station. As a further alternative, the terminal could operate outside of the GSM rules since any base station will allocate a channel and transmit TA

information before determining whether the terminal has a valid subscription to the network. For example, since each MT carries the BA list (i.e. a list of BCCH frequencies that can be received at that MT at that moment in time) the MT could be controlled to attempt to use BCCH other than that which has the highest signal strength at that point in time.

Once the base station has been contacted, the next step (step 66) is to receive TA information which indicates the degree to which the transmission timing of the terminal must be adjusted to fit within the timeslot allocated to that terminal by the base station.

These three steps (steps 62, 64 and 66) are then repeated until TA information has been obtained from at least three base stations (of the same or different networks). As an option, more than three base stations can be contacted to improve the accuracy of the position determination procedure. The number of base stations to be contacted could even be a variable defined by a user of the terminal in dependence upon the accuracy of position determination required.

Once the TA information has been obtained from the base stations, the PDM calculates, in step 68, the distance from the terminal to each of the base stations by means of the following formula:

$$D = (TA/2) \times c$$

where:

D is the distance (in metres) from the mobile terminal to a base station

TA is the timing advance adjustment (in microseconds) provided by

the base station (N.B. one bit period ≈ 3.69 microseconds); and

c is the speed of light (approximately 300 x 10^6 m/s).

Once the PDM has calculated the distances between the terminal and each of the base stations it then calculates, in step 70, the position of the terminal with respect to the base stations contacted. This step of the procedure could be accomplished by means of the well known triangulation or circle method, or indeed by any other method.

Once the PDM has calculated its position relative to the base stations, it could display the position of the terminal (with respect to the base stations) to the user of the mobile terminal, but as this position information is likely to be fairly useless (because it will only specify the position of the terminal with reference to three unknown geographic locations) it is preferred to continue and convert, in step 72, the position information calculated in step 70 into a geographic location.

This conversion could be accomplished, for example, by storing (in a SIM for example) a database of information that uniquely identifies the BTSs (using information such as, in combination, the base station identity codes (BSIC), the MNC (mobile network code) and other identifying information) and respective geographic positions (for example in terms of base station longitudes and latitudes).

Using this unique information, it would be possible for the PDM to look up the longitude and latitude of each base station contacted in the aforementioned procedure, and then calculate the position of the terminal (in

terms of its longitude and latitude) based on the longitude and latitude of the (at least) three base stations contacted. The longitude and latitude information for base stations of a given network could be provided by the network operator, or alternatively it could be acquired by means of a survey where the location of base stations (which tend to be quite conspicuous) can be observed by travelling around a cell or cells of a given network.

As a further option, the base station longitude and latitude information could be transmitted as a message (such as an SMS message - possibly transmitted after the TA signals from a given base station) on receipt of a suitable request from the mobile terminal. The longitude and latitude information, if transmitted over the air interface, could be encrypted to avoid any security problems that might result if information revealing the position of base stations in a network were to become available to the public.

As a further option (which would be of particular utility if the base station were to be housed near a landmark of some description), the PDM could present the position information as a message informing the user that they "are currently X metres south-west, for example, of a particular point". This option would perhaps be of more utility than merely displaying longitude and latitude information since it is likely that the difference in longitude and/or latitude will only be a matter of a few degrees (maybe even less), between the extremes of a given cell. It is even conceivable that the position information might be displayed in terms of a map or plan of the local area.

Once the geographical location of the terminal has been calculated it is

displayed to the user of the terminal in step 74, and the PDM procedure is subsequently terminated.

MOBILE TERMINAL ARCHITECTURE

In its simplest incarnation, the mobile terminal of the present invention is similar to that shown in Fig. 3 and comprises, in addition, only the PDM described above. A terminal of this type would be advantageous over the systems described in the prior art because it would allow a user of the terminal to accurately determine his position without having to reveal that position to the network or to the network operators.

Accordingly, in a first embodiment of the invention the mobile terminal simply comprises (in addition to the components schematically shown in Fig. 3), as software or alternatively as hardware (such as an ASIC for example), a PDM of the type described above in relation to Fig. 4. Such a terminal could be used to contact, in succession, three different base stations (from, for example, the cell in which the terminal is currently located and two neighbouring cells) of a given PLMN (public land mobile network) that the terminal is permitted by the SIM to access to determine the position of the terminal.

As an alternative, the terminal could be operated outside of the GSM rules to contact one or more base stations from its home network (i.e. the network that the user is permitted by the SIM to access) and one or more other base stations from a different PLMN or different PLMNs. In such a situation, the base stations of the different PLMN(s) would return the TA information

required to determine the position of the mobile terminal before determining that the SIM of the terminal does not permit access to that particular network.

It is even conceivable for the terminal to be operated to attempt to connect to three base stations to which access is not permitted by the SIM solely for the purposes of retrieving TA information from the base stations (that information automatically being provided even if a dedicated channel is subsequently not established). However, this approach would probably be discouraged by the network operators because they would be unable to charge for access to their networks.

Since such an approach would be advantageous to users, it is conceivable that the network operators could be persuaded to issue SIM cards which would provide limited access to a given network for the purposes of location determination. Such a solution would be advantageous for users since it is likely that the accuracy of position determination would be increased by connecting to base stations of different PLMNs (principally because a user would be more likely to be able to connect to a plurality of BTSs). It is also the case that it is more likely, particularly in an urban environment, to be able to successfully contact at least three base stations of different PLMNs than three base stations of the same PLMN.

In a more complicated incarnation, the mobile terminal of a second embodiment of the invention could comprise three transmitter circuits, three receiver circuits, and three SIMs – one for each transmitter/receiver circuit pair. Fig. 5 is a schematic representation of such a terminal.

As shown, the terminal 80 includes a first transmitter circuit 82, a first receiver circuit 84, a second transmitter circuit 86, a second receiver circuit 88, a third transmitter circuit 90 and a third receiver circuit 92. Coupled to each of the transmitter / receiver pairs is a microcontroller 94 that is in turn connected to three SIM cards 96, one card being provided for each transmitter / receiver pair. In this embodiment of the invention, each SIM card provides access to a different PLMN. Other circuitry (indicated generally by reference numeral 100) not material to the invention is also provided. Of course, it will be appreciated that less or more than three SIMs may be provided, and that the SIMs need not be hard wired to any particular transmitter / receiver pair but could instead be dynamically assignable to the transmitter / receiver pairs (for example one SIM coupled to more than one transmitter / receiver pair) as necessary. It will furthermore be appreciated that the SIMs need not necessarily provide access to different PLMNs.

In this embodiment, one of the SIM cards includes a SIM Toolkit and a PDM such as that described above. As an alternative, the PDM could be provided in memory (not shown) for execution by the microcontroller.

To determine the position of the terminal the PDM controls the first, second and third transmitters to simultaneously (or at least substantially simultaneously) contact a base station of the PLMN to which the associated SIMs permit access. As described above, the base stations respond with appropriate TA signals, and the PDM can calculate the position of the terminal with respect to the base stations and subsequently the geographic

location of the terminal.

The chief advantage of this embodiment, compared to the above described first embodiment, is that as the base stations are contacted simultaneously, accuracy problems associated with movement of the terminal can be avoided. Another advantage of this embodiment is that the terminal is less likely to be unable to contact at least three base stations, as well as being less likely to fall foul of problems that can arise when base stations are located too close to one another to permit an accurate position determination to be made.

It will no doubt be apparent to persons skilled in the art that a large number of alternative arrangements are possible which can avoid one or more of the problems described above. All such arrangements fall within the scope of the invention.

For example, it has previously been proposed in co-pending United Kingdom Patent Application No. 0125921.7 - filed on 29 October 2001 (the contents of which are incorporated herein by reference) - to provide a terminal where transmitter / receiver pairs are shared, for example, between SIMs of different PLMNs.

Figs. 6 to 8 are schematic illustrations of the terminals described in the above mentioned UK patent application. As will be appreciated following a study of the following description, these figures show, in general terms, mobile terminals which are provided with at least one transmitter circuit, at least two receiver circuits and at least two SIMs.

Fig. 6 is a schematic representation of a mobile terminal 101 according to a third embodiment of the present invention. In this embodiment, a second SIM 102 is provided in addition to the first SIM 32 of the Fig. 3 terminal. As with the arrangement of Fig. 3, each SIM permits access to a network operated by a particular (not necessarily different) network operator.

In the terminal of Fig. 6, both SIMs are connected to and controlled by the microcontroller 36, and elements of the terminal which correspond to those of Fig. 3 are referenced by common reference numerals.

The terminal of this embodiment comprises one transmitter circuit 38 and two receiver circuits 40 and 104. Each of the two receiver circuits 40, 104 is provided with the receiver circuit components shown in Fig. 4. For example, a second channel decoder 106, GMSK demodulator 108 and baseband filter 110 (as well as other components) are provided.

A multiplexer 120 is connected to the two receiver circuits 40 and 104, and to the transmitter circuit 38. In this way the terminal can share the two receiver circuits for different applications. The terminal is provided with a PDM which can be operated to contact two base stations with one SIM, and one base station with the other SIM. The presence of two receiver circuits allows TA signals from two different base stations to be received substantially simultaneously, and this can help reduce the impact of terminal movement on position determination accuracy. Furthermore, the two SIM cards can be arranged to permit access to two different PLMNs to improve the likelihood

of being able to contact three base stations.

It will be appreciated that despite the fact that the terminal of Fig. 6 has only a single transmitter, two access bursts can be transmitted virtually simultaneously (i.e. within a few milliseconds of one another).

Fig. 7 illustrates a terminal 130 in accordance with a fourth embodiment of the present invention. In this embodiment the terminal comprises two transmitter circuits 38 and 132, and two receiver circuits 40 and 104. As with the embodiment shown in Fig. 6, all elements related to the receiver circuit and all elements related to the transmitter circuit are provided twice. The two receiver circuits 40, 104 and the two transmitter circuits 38, 132 are connected to a multiplexer 120. The mobile terminal described above is able to receive "p" different SIM cards (as shown) and is further able to share the two receivers and two transmitter circuits between different applications of the "p" subscriptions.

Fig. 8 illustrates a terminal 150 in accordance with a fifth embodiment of the invention. Here two transmitter circuits (38 and 132) and three receiver circuits (40, 104 and 152) are provided. All receiver and transmitter circuits are connected to a multiplexer 120. Again, the terminal is adapted to receive "p" different SIM cards, and the microcontroller 36 controls the distribution of the receiver and transmitter circuits to the applications of the "p" subscriptions.

As will be appreciated by persons skilled in the art, the embodiments shown in Figs. 7 and 8 provided advantages over systems disclosed in the

prior art that are similar to those of the other embodiments.

It will be understood, of course, that whilst a number of preferred embodiments have been described, these embodiments are described by way of example only and thus that they should not be read as limiting the scope of the invention in any way. It will also be understood, and should be noted, that modifications and alterations to the particular embodiments described may be made without departing from the scope of the invention as defined in the accompanying claims.

For example, whilst it is preferred that common elements of the transmitter and/or receiver circuits of the embodiments described are duplicated, it will be appreciated by persons skilled in the art that respective transmitter and/or receiver circuits could share some or all of the common components.

It will also be understood, and should be noted, that the mobile terminals described above with "p" SIM cards can be arranged to permit subscription to "p" different *service providers*, to permit "p" different subscriptions with *one and the same service provider* or a combination of these options.

It will also be apparent to persons skilled in the art that base stations are typically capable of much more accurate TA measurements than are normally required to establish a communications channel. This more accurate TA information could be transmitted, on receipt of an appropriate request, to a given PDM to improve the accuracy of position determination.

It will also be apparent, and should be noted, that whilst in most cases the air path propagation is usually the most significant component of time delay in signal transmission, propagation delays in electronic circuits may also have an effect when a more accurate determination of terminal position is required. To combat this problem a given mobile terminal may be provided, at the time of its manufacture for example, with values indicating the adjustment required to counter act propagation delays resulting from the circuitry of the terminal. Similarly, base stations could be adapted to transmit correction information for delays caused by the base station signal reception and transmission circuitry. In this way, a highly accurate distance determination could be accomplished by subtracting the terminal and base station circuitry delays from the transmitted TA signal before the distance from the terminal to the base station in question is calculated.

It will be appreciated that the principles of the present invention can be useful to provide a continuous update of position information by maintaining channels to the base stations whereupon TA signals will continuously be transmitted to the MT.

It will also be appreciated that whilst it is normal for a SIM to provide a single subscription to a single network, a SIM could be arranged to provide multiple subscriptions to a single network or even to provide access to multiple networks. It will also be appreciated that subscriber identifying means other than a SIM card may be used.

CLAIMS

1. A mobile terminal comprising means for determining the distance of the terminal from each of at least three base stations of one or more terrestrial communication networks; and means for calculating from said determined distances the position of said terminal with respect to said at least three base stations.

2. A terminal according to Claim 1, further comprising means for calculating the geographic location of said mobile terminal from said calculated terminal position and geographic location information specifying the geographic location of said at least three base stations.

3. A terminal according to Claim 2, wherein said geographic location information comprises the longitude and latitude of said at least three base stations.

4. A terminal according to Claim 2 or 3, wherein said geographic location information is transmitted from said at least three base stations to said mobile terminal upon receipt of a request for location information issued by said mobile terminal.

5. A terminal according to any preceding claim, comprising means for

establishing a connection to said at least three base stations, and means for receiving timing advance signals from said at least three base stations.

6. A terminal according to Claim 5, wherein said determining means is operable to calculate the distance between said terminal and a said base station of said at least three base stations in accordance with the following formula:

$$D = (TA/2) \times c$$

where:

D is the distance from said mobile terminal to a said base station;

TA is said timing advance signal provided by said base station; and

c is the speed of light.

7. A terminal according to any preceding claim, wherein said at least three base stations are base stations of the same telecommunications network.

8. A terminal according to any of claims 1 to 6, wherein said at least three base stations are base stations of different telecommunications networks.

9. A terminal according to any of Claims 1 to 6, wherein at least two of said at least three base stations are base stations of different telecommunications networks.

10. A terminal according to any of Claims 6 to 9, comprising at least one receiver circuit and at least one transmitter circuit.

11. A terminal according to Claim 10 when dependent on Claim 8, comprising one transmitter/receiver circuit pair and one subscriber information storage device for each of said at least three base stations.

12. A terminal according to any of claims 1 to 6, comprising n receiver circuits and m transmitter circuits, said terminal being adapted to receive p subscriber identifying means, wherein each subscriber identifying means provides access to services according to a particular subscription, and wherein $n \geq 2$, $m \geq 1$ and $p \geq 2$.

13. A mobile terminal according to claim 12, wherein $n \neq m$.

14. A mobile terminal according to claim 12 or 13, wherein $n > m$.

15. A mobile terminal according to claim 12, 13, or 14, wherein $p > n$.

16. A mobile terminal according to any of claims 11 to 15, wherein $m \geq 2$.

17. A mobile terminal according to any preceding claim, wherein said one or more telecommunications networks are cellular telecommunications networks.

18. A mobile terminal according to Claim 17, wherein said cellular telecommunications networks are GSM compliant networks.

19. A method comprising the steps of: determining the distance of a mobile terminal from each of at least three base stations of one or more communication networks; and calculating from said determined distances the position of said terminal with respect to said at least three base stations.

20. A method according to Claim 19, comprising the steps of establishing a connection to said at least three base stations, and receiving timing advance signals from said at least three base stations.

21. A method according to Claim 20, wherein connections are established at least substantially simultaneously to said at least three base stations.

22. A method according to Claim 20 or 21, wherein said determining step comprises calculating the distance between said terminal and a said base station of said at least three base stations in accordance with the following formula:

$$D = (TA/2) \times c$$

where:

D is the distance from said mobile terminal to a said base station;

TA is said timing advance signal provided by said base station; and

c is the speed of light.

23. A computer program comprising one or more software portions which when executed in an execution environment are operable to perform one or more of the steps of the method set out in any of Claims 19 to 22.

24. A terminal substantially as hereinbefore described with reference to Figures 3 and 5 to 8 of the accompanying drawings.

25. A method substantially as hereinbefore described with reference to Figure 4 of the accompanying drawings.

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Application No: GB 0129726.6
Claims searched: 1 to 25
Examiner: Brian Hughes
Date of search: 17 September 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): H4L (LRPLS) H4D (DAB, DPBX)

Int Cl (Ed.7): G01S 5/14; G01S 11/02, 11/06, 11/08

Other: Online: EPODOC, WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2366490 A	(ROKE MANOR RESEARCH) Page 5 line 1 to page 6 line 26	1, 5, 7 to 10, 17, 19 and 20
X	GB 2350018 A	(MOTOROLA) Page 6 lines 1 to 16	1, 7 to 10 and 17 to 19
X	GB 2346516 A	(ERICSSON) Page 3 line 22 to page 6 line 28	1, 7 to 10 and 17 to 19
X	EP 1093318 A2	(LUCENT) Page 3 line 53 to page 4 line 20	1, 7 to 10 and 19
X	EP 0320913 A2	(NOKIA) Column 3 line 32 to column 4 line 54	1, 2 and 19
X	WO 98/15149 A1	(NOKIA) Page 4 line 1 to page 9 line 25	1, 5, 7 to 10, 17 to 20 and 23
X	US 5960355	(EKMAN et al) Column 5 line 18 to column 11 line 49	1, 7 to 10 and 17 to 19

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